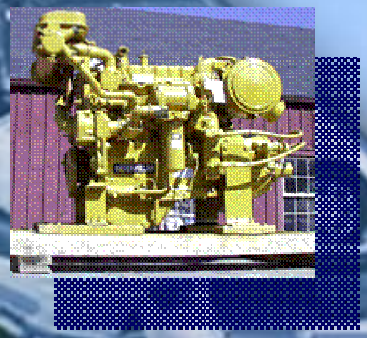
South Coast Air Quality Management District
Ultrafine Particle Conference
Los Angeles, April 30 – May 2, 2006
Session Six – Technology II-Fuels/Aftertreatment

Methods and Characterization of Ultrafine Particles in Various Engine Exhaust Aerosols



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Acknowledgements

- **Jorn Herner**

  Air Resources Engineer
  Emission Control Technology Research
  California Air Resources Board

  PhD Candidate
  Civil and Environmental Engineering
  University of California, Davis

- **CARB Staff at Emissions Laboratories**

- **TSI Inc. kindly provided some instruments for our studies**

DISCLAIMER

The statements and opinions expressed in this presentation are solely the author's and do not represent the official position of the California Air Resources Board. The mention of trade names, products, and organizations does not constitute endorsement or recommendation for use.

Overview

- The universe of ultrafine particle sources
- CARB's research priorities and characterization of ultrafine particle emissions
- Challenges associated with measurement
- California's contributions to the European PMP advances

The challenge before us: the universe of UFP sources

The anthropogenic sources of ultrafine particles are numerous (stationary, mobile, industrial, occupational, atmopheric conversion)

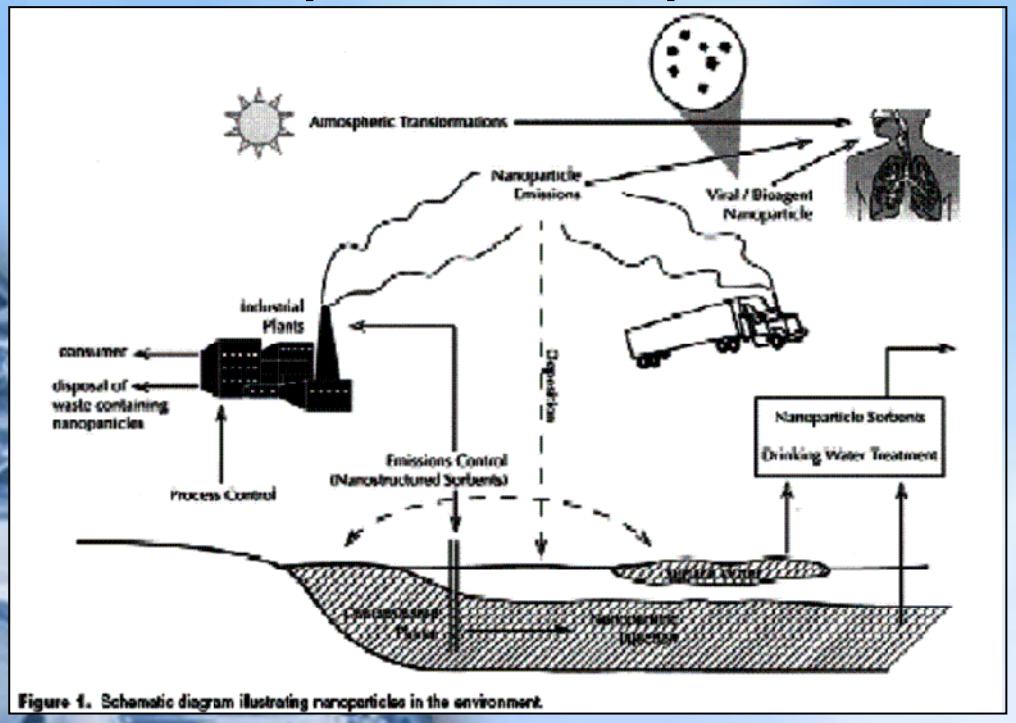

Figure 1. Schematic diagram illustrating nanoparticles in the environment.

Biswas and Wu, *J. Air & Waste Manage. Assoc.* **2005**

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Mobile sources are a key focus

Ultrafine particle emissions:

- **Not a “diesel-only” problem**
- **Ultrafine particles originate almost exclusively from combustion processes**
- **Diesel, gasoline, LNG, LPG, CNG, jet aircraft engines have all been identified as sources of ultrafine particles emissions**

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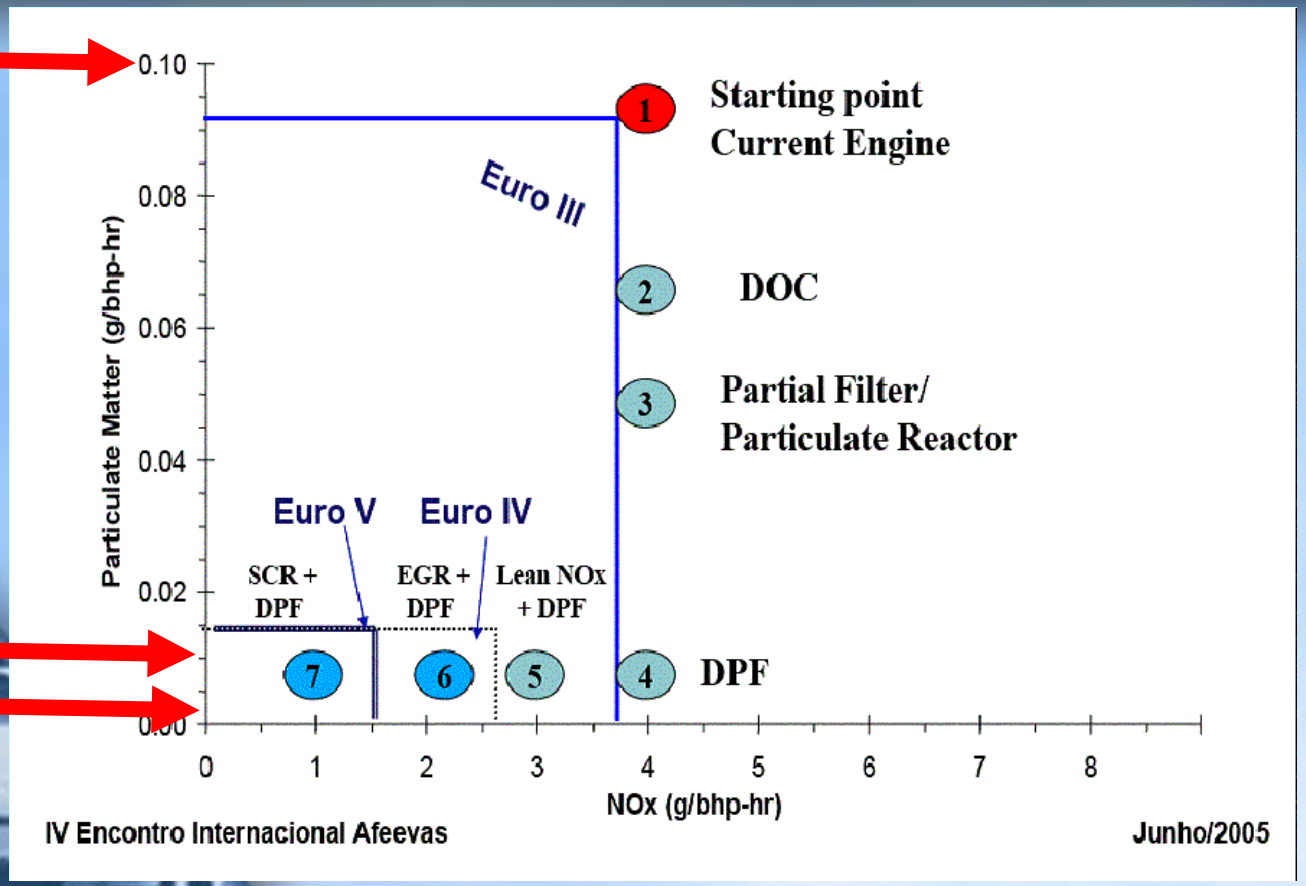
The technology roadmap to lower HD diesel engine emissions is clear

Current CA standard

2007 CA standard

CRC E66 emissions



Taylor, T.Q., "Diesel Retrofit, Today's Practical Applications," IV Vehicle Emissions International Conference, Brasilia, June 2005

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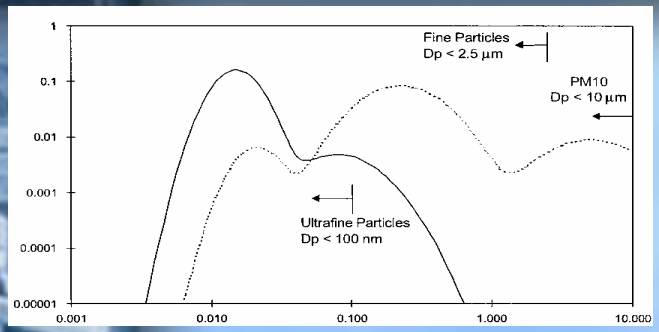
Weak correlation between particle mass and number



Picture from D.A. Allison, *CAPCOA Conference*, Aug. **2005**

- *Ultrafine particles constitute a small fraction of PM mass, but dominate the fraction of particle number (and surface area)*
- *PM mass emission control may not equal particle number emission control*
- *Ultrafine particles have different chemical composition from fine or coarse particles. They consist almost exclusively of organic and elemental carbon**
- *"Ultrafine particles" still an emerging environmental area*
- *Agreed-upon methodologies for measurement of ultrafine particle emissions do not exist*

* Herner et al., *J. Air & Waste Manage. Assoc.* **2005**

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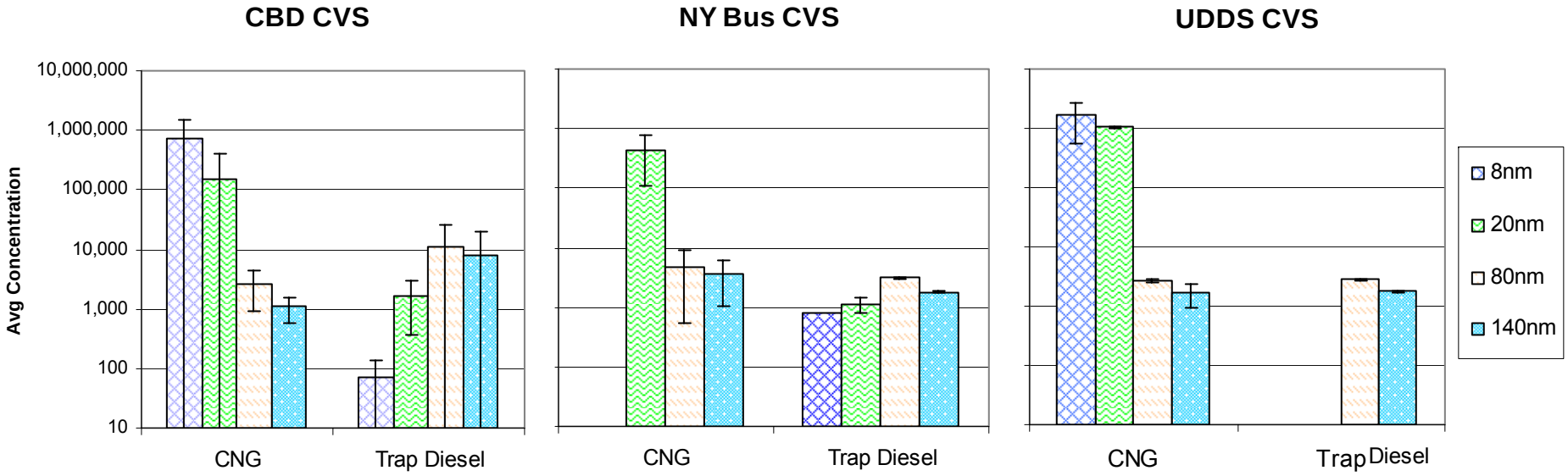
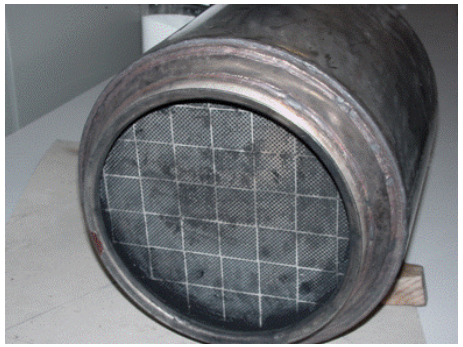
Under the research priorities* "Reduction of emissions and characterization of air pollutants," CARB has significant on-going investigations of emission control technologies and methods for sampling for ultrafine particles

*2001-2010 Strategic Plan for Research

April 2003 Update

Ultrafine Particle Emissions for CNG and Trap-equipped Diesel



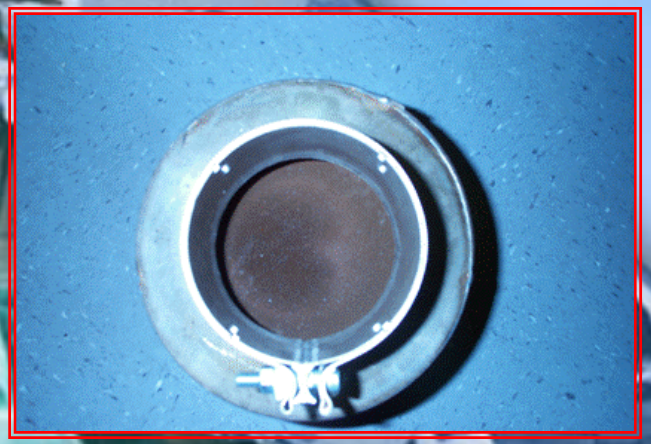


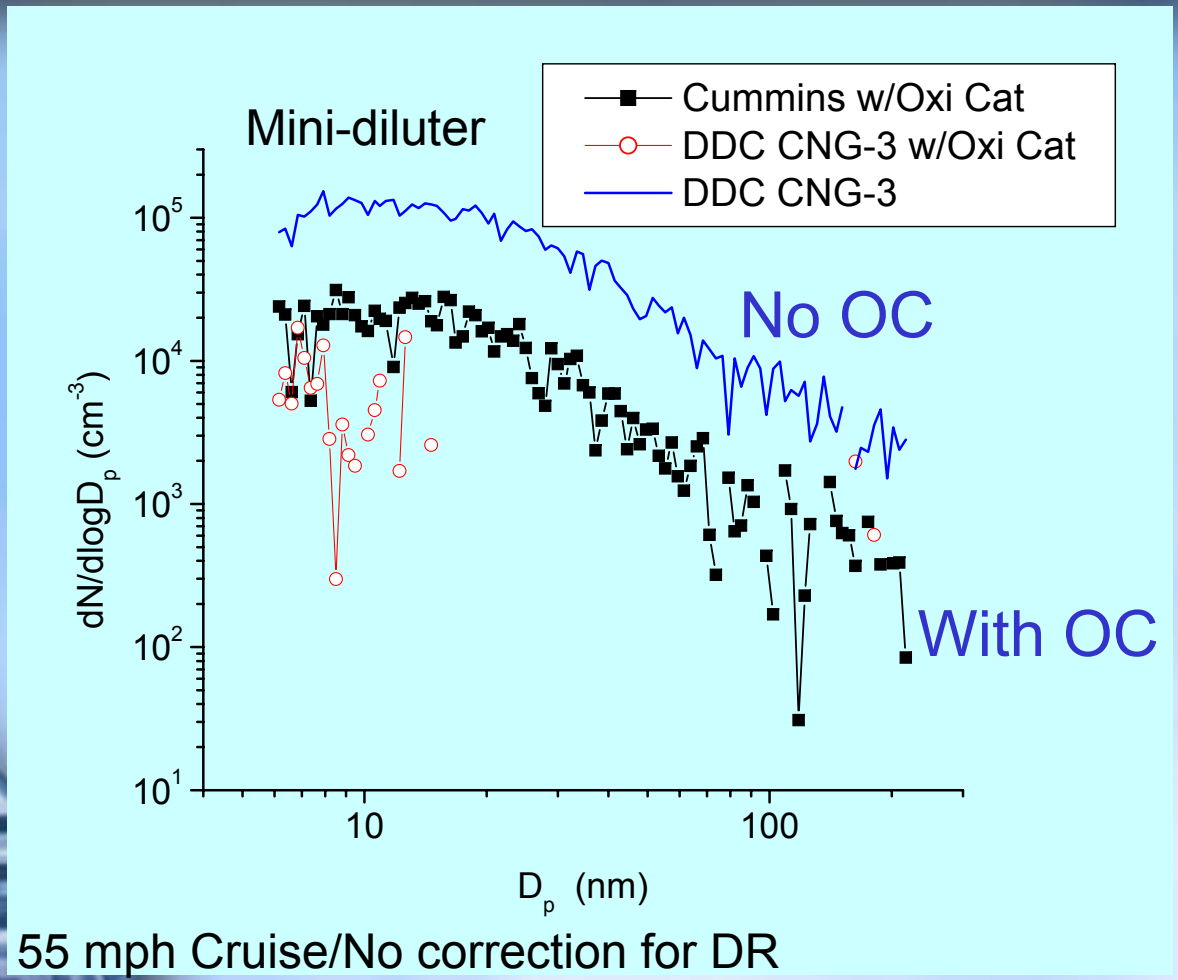
- Comparison of cycles (cycle mean concentrations)
- Particle number distribution peaks at 8nm for CNG and at 80nm for trap-equipped diesel
- Average concentrations vary between cycles

* Error bars represent 1 standard deviation of repeated samples.

Adapted from Holmen and Ayala, *Environ. Sci. Technol*. **2002**

Oxidation Catalyst Control on CNG Emissions





55 mph Cruise/No correction for DR

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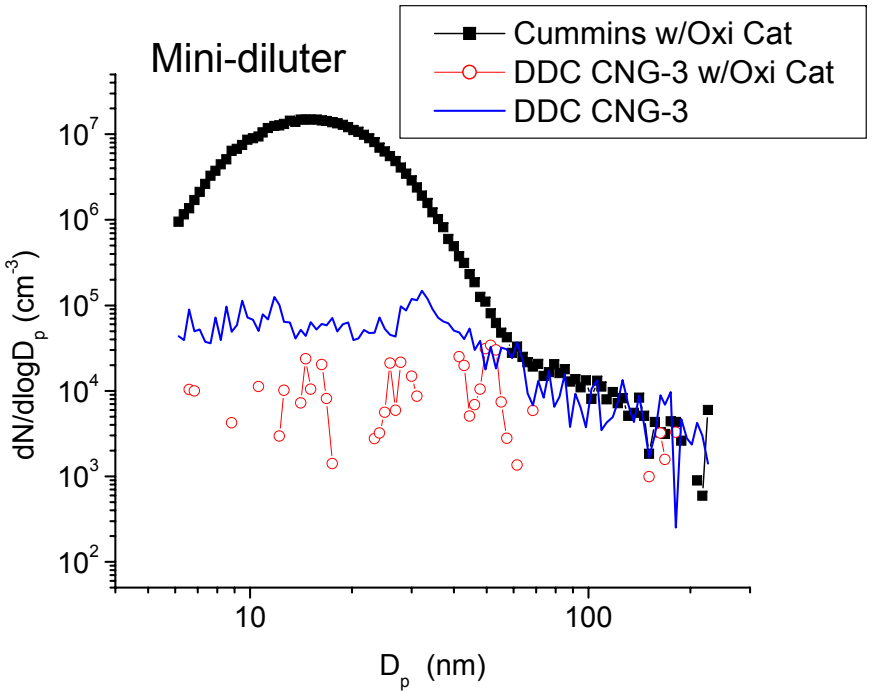
Ayala & Holmen, CRC On-Road Emissions Workshop, San Diego, **2003**

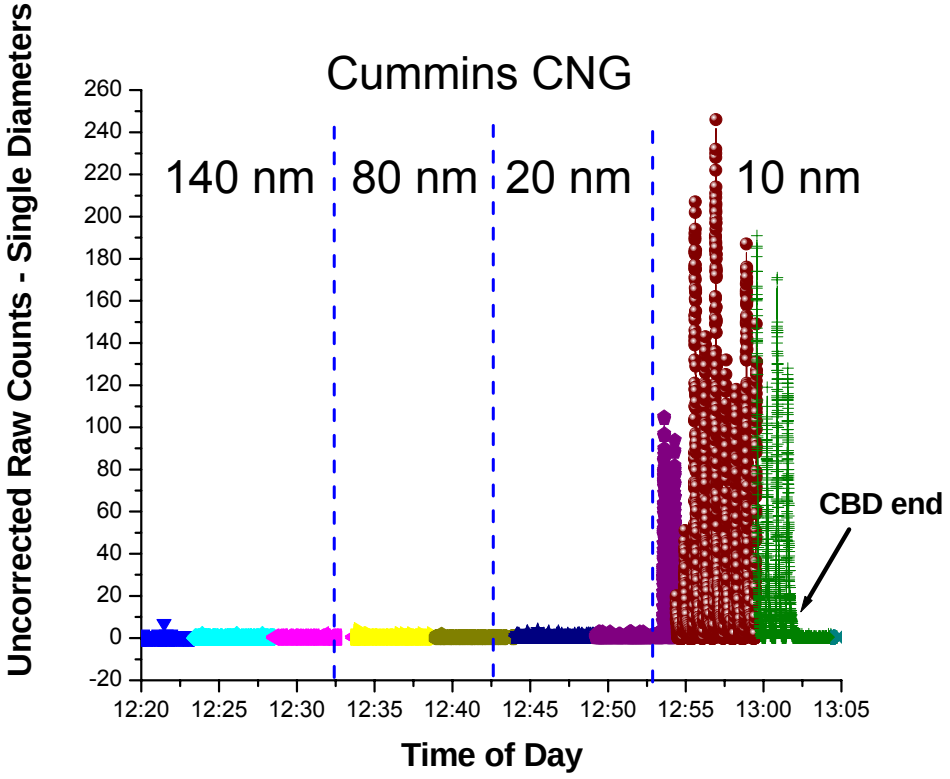
Strong Dependence on Engine Operation

(OC-equipped CNG engine)



Idle

(No correction for DR)



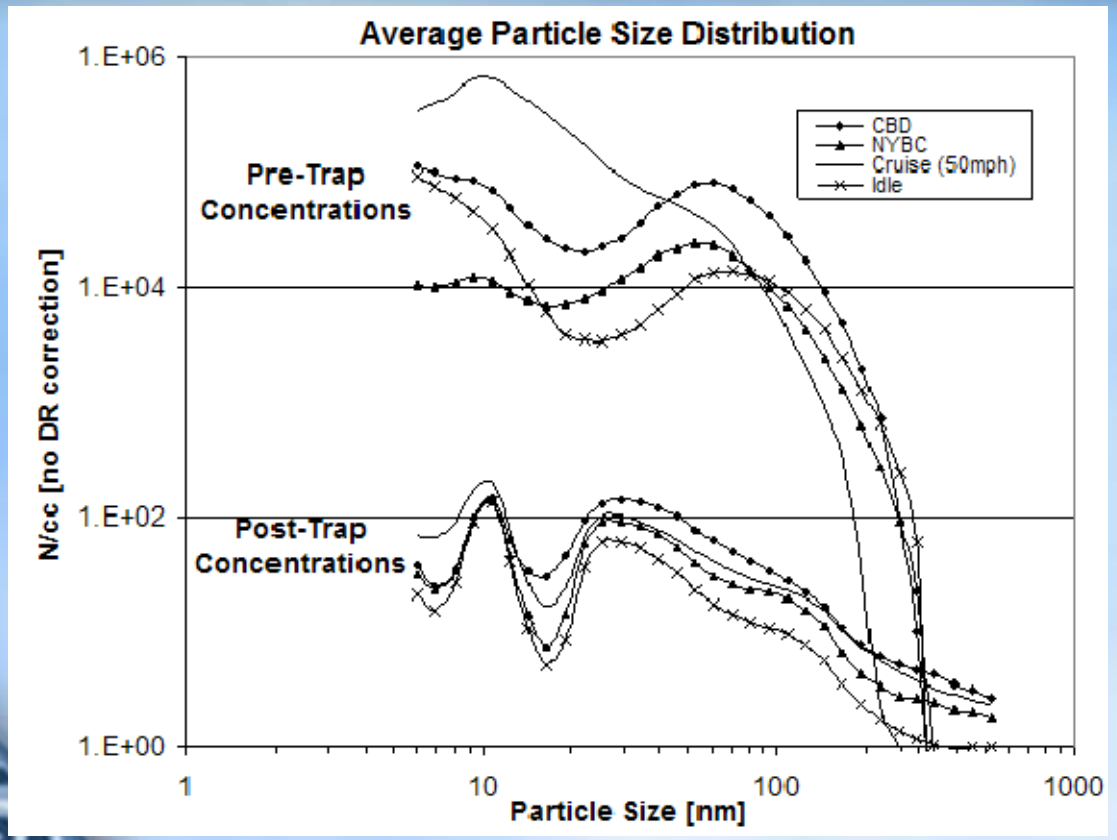
Transient Cycle (CBD)

(No correction for DR)

Each color represents one cycle

Ayala & Holmen, CRC On-Road Emissions Workshop, San Diego, **2003**

DPF reductions confirmed in laboratory tests



- Partial flow
- No heating
- Two Stage dilution
- Low dilution ratios (8x8)

Ayala and Herner, *J. of Lubricants and Fuels*, SAE Transactions, **2005**

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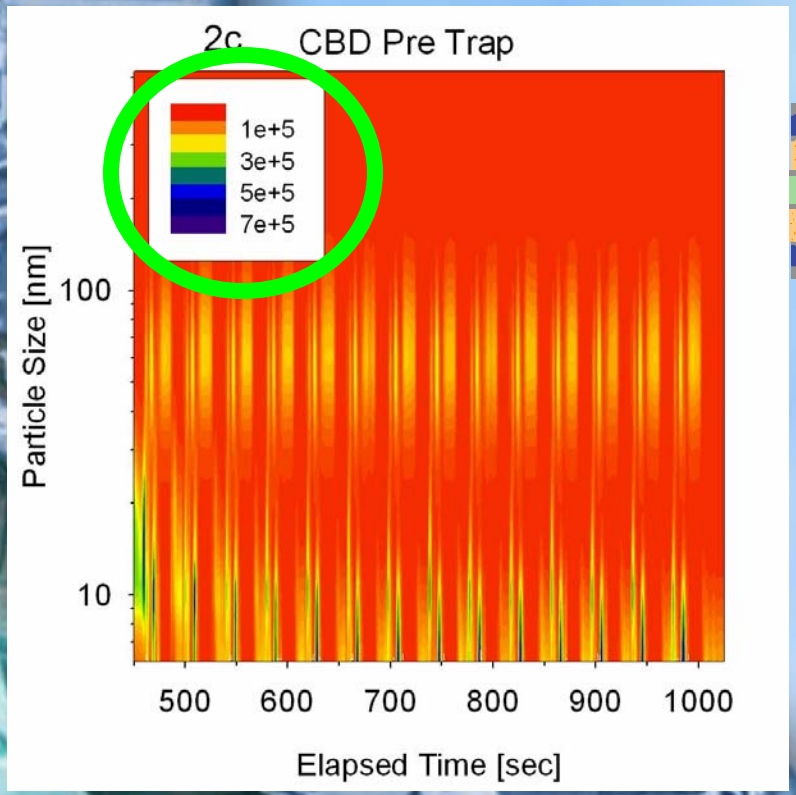
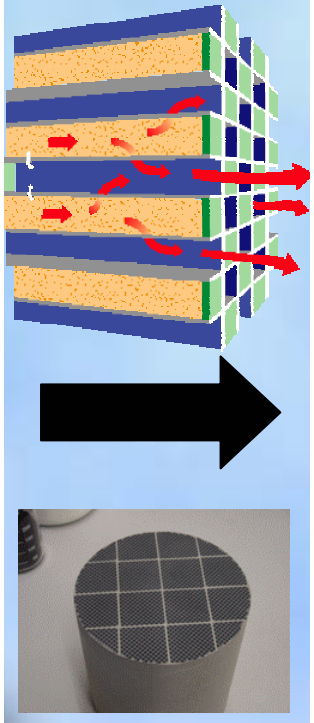
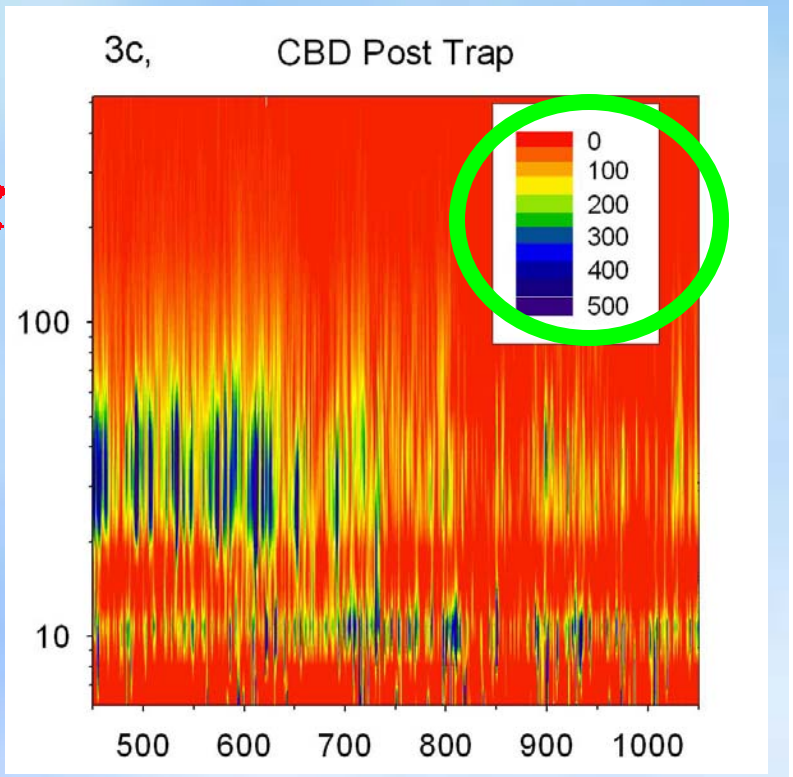
New fast sizing instruments allow for examination of transient emissions

No correction for dilution

Note different scales



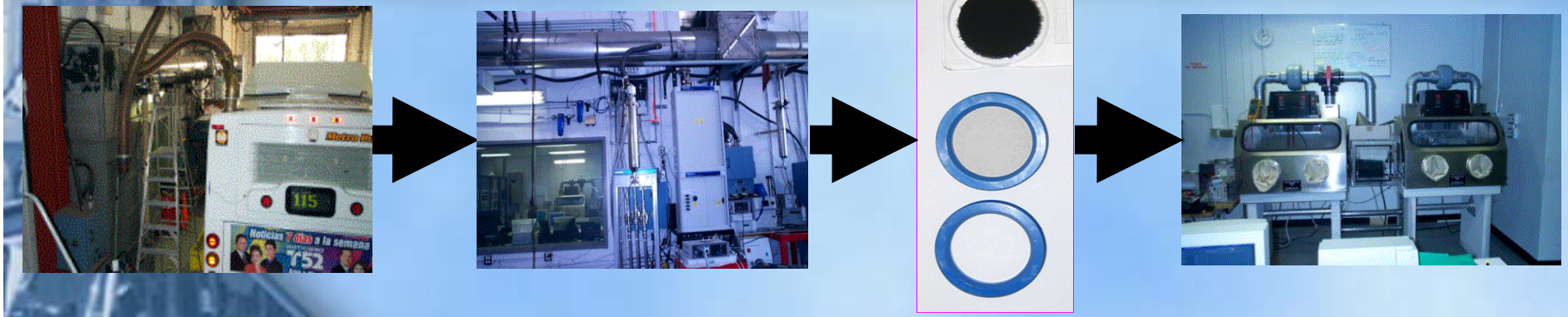




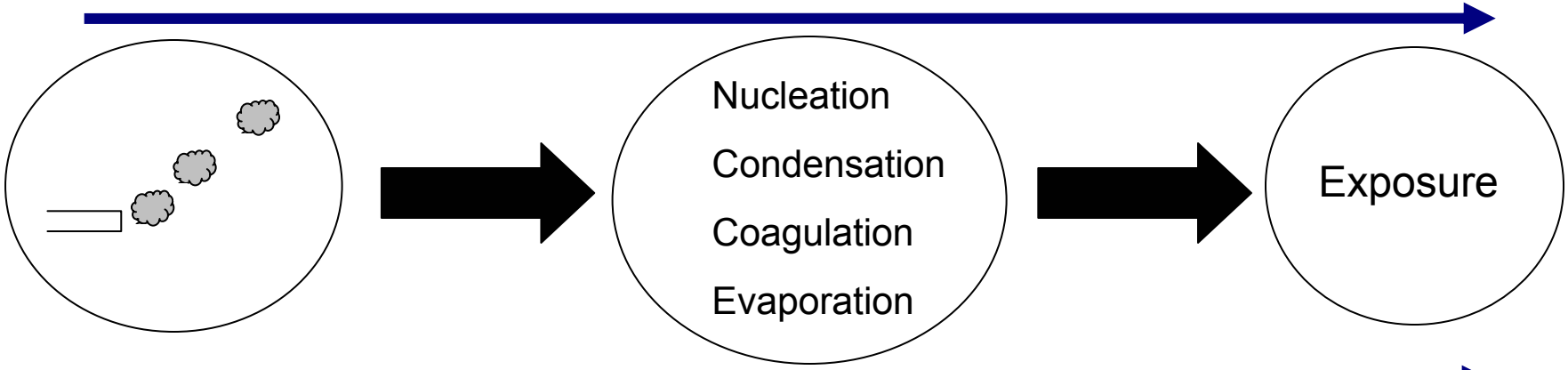
Ayala and Herner, *J. of Lubricants and Fuels*, SAE Transactions, **2005**

PM is operationally defined*

Laboratories for certification of compliance with mass emission standards



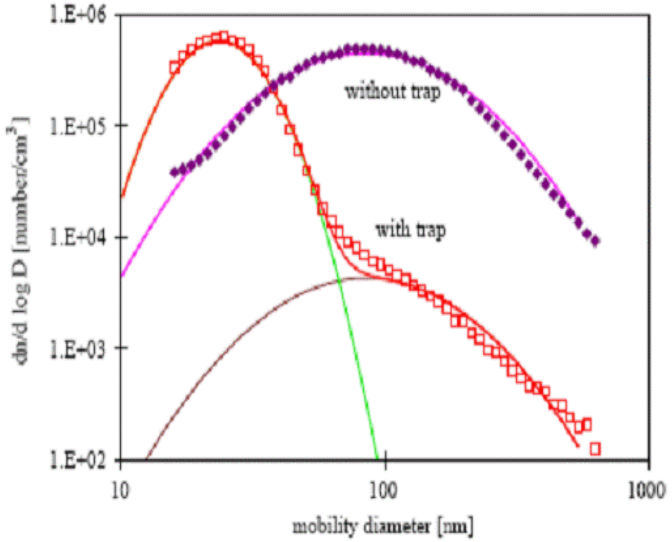
Different measurement methods



Different vehicle emission behavior

*CFR Part 1065

Nucleation Mode Particles in Exhaust Emissions and in the Ambient



H. Burtscher / Aerosol Science 36 (2005) 896–932

Effect of DPF

- Some research evidence suggests that a DPF can cause higher numbers of ultrafine particles while still reducing PM (nucleation of volatile material)
- Effect of sampling conditions and application to real world conditions poorly understood

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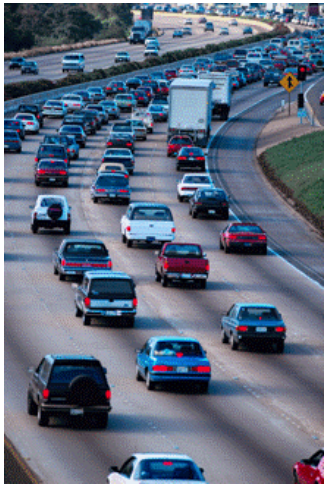
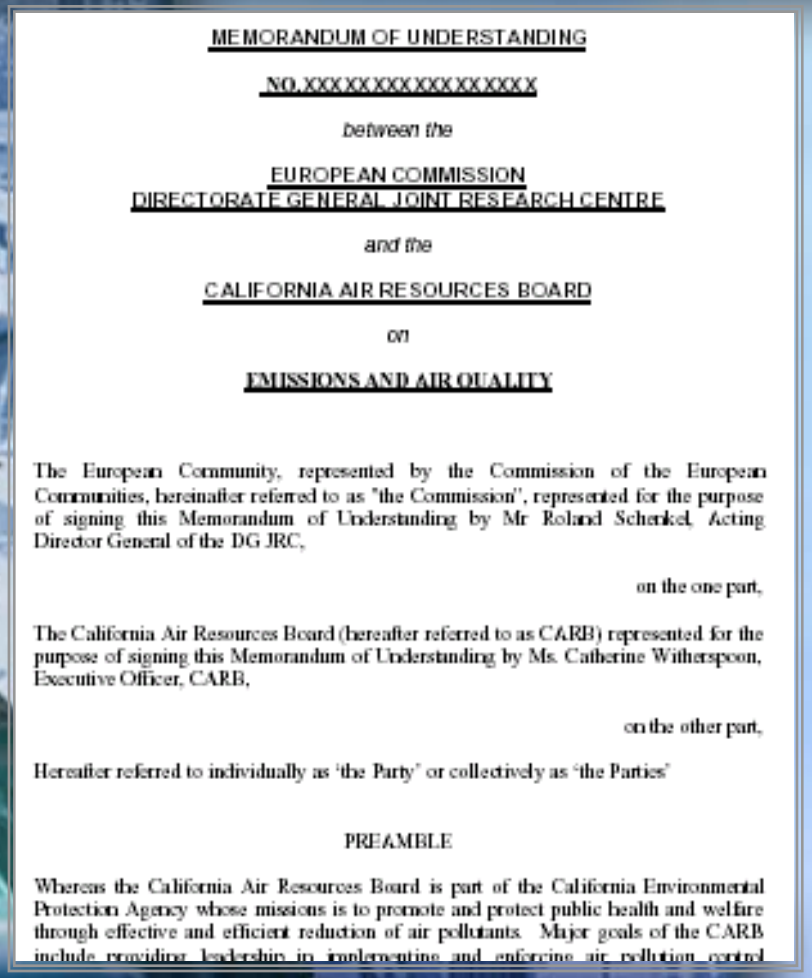


Particle numbers measured on the roadway appear to be different than laboratory measurements

Advancing international cooperation with new EU-DG-JRC & CARB partnership



MEMORANDUM OF UNDERSTANDING

NO.XXXXXXXXXXXXXXXX

between the

EUROPEAN COMMISSION
DIRECTORATE GENERAL JOINT RESEARCH CENTRE

and the

CALIFORNIA AIR RESOURCES BOARD

on

EMISSIONS AND AIR QUALITY

The European Community, represented by the Commission of the European Communities, hereinafter referred to as "the Commission", represented for the purpose of signing this Memorandum of Understanding by Mr Roland Schenkel, Acting Director General of the DG JRC,

on the one part,

The California Air Resources Board (hereafter referred to as CARB) represented for the purpose of signing this Memorandum of Understanding by Ms. Catherine Witherspoon, Executive Officer, CARB,

on the other part,

Hereafter referred to individually as 'the Party' or collectively as 'the Parties'

PREAMBLE

Whereas the California Air Resources Board is part of the California Environmental Protection Agency whose missions is to promote and protect public health and welfare through effective and efficient reduction of air pollutants. Major goals of the CARB include providing leadership in implementing and enforcing air pollution control

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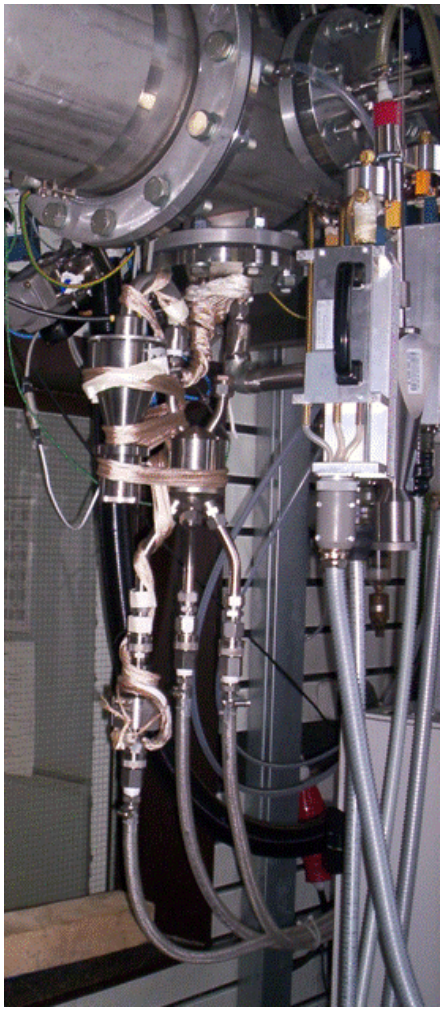
MOU subject areas:

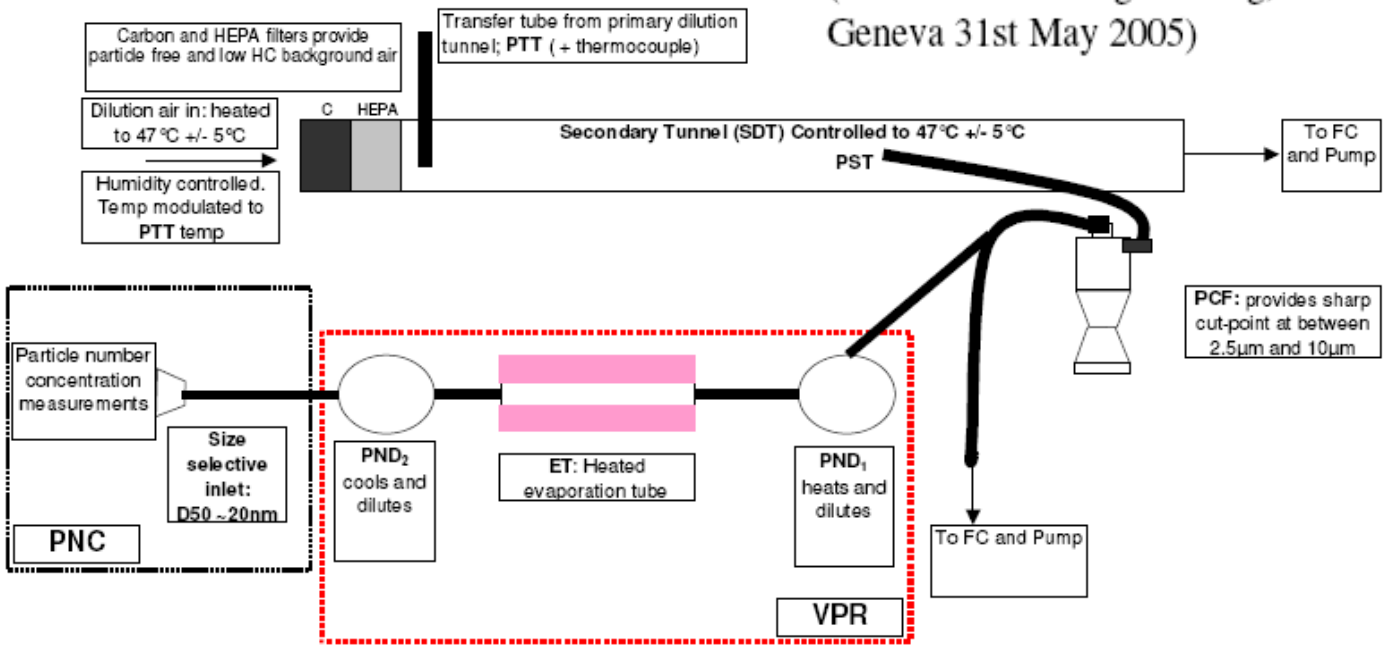
- Mass emission measurement (in laboratory and on board vehicle)
- Ultrafine particle emissions & PMP
- Source apportionment
- Climate change

The PMP Protocol



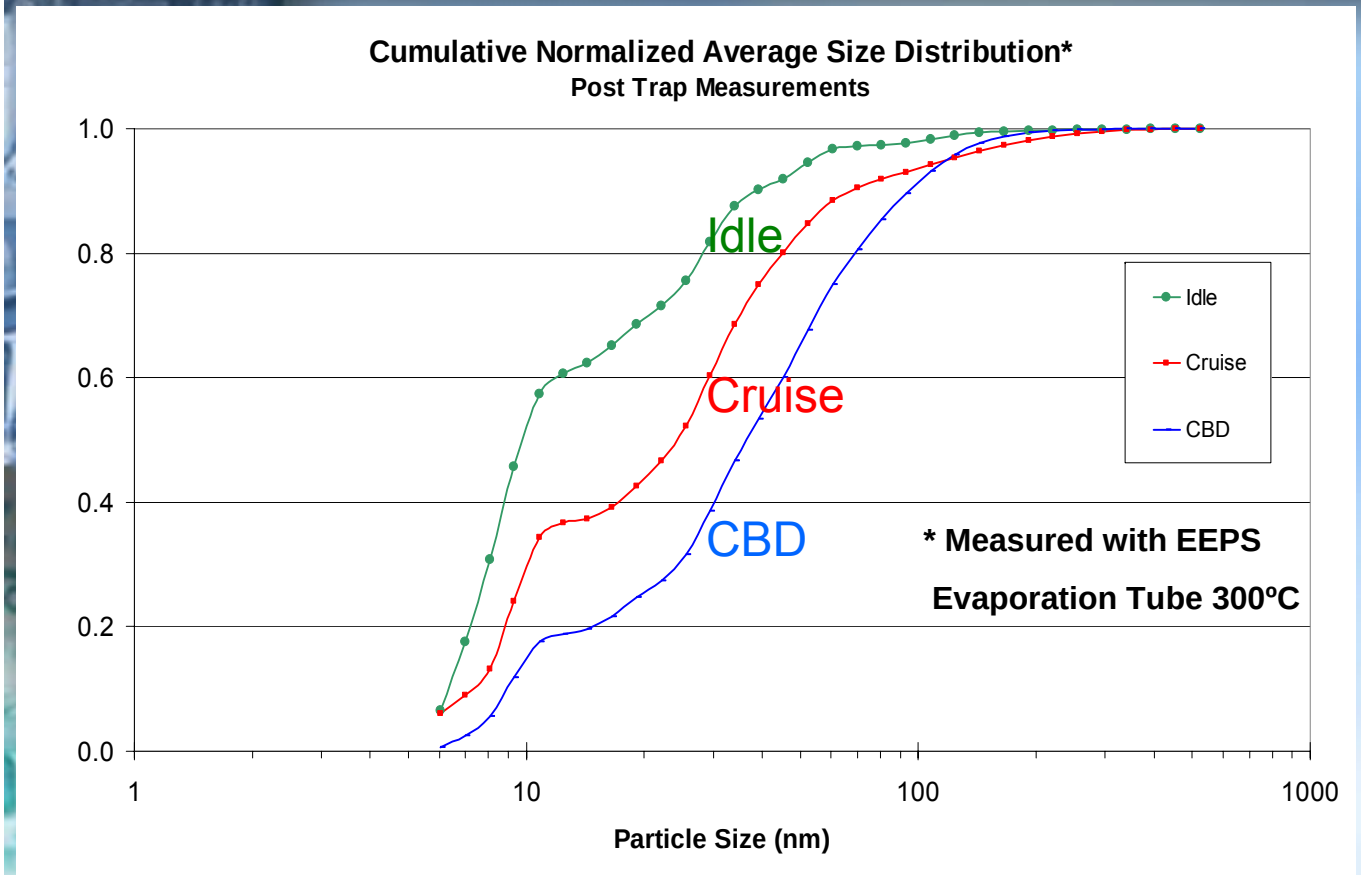
Picture courtesy of P. Dilara

Working paper No. GRPE-PMP-15-4
(15th PMP working meeting,
Geneva 31st May 2005)

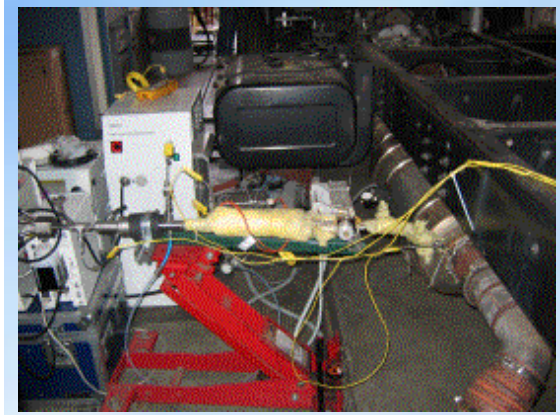


- **New proposed solid particle number emission standard for CI and GDI light-duty vehicles**
- **Proposed protocol for measurement**
- **Counting solid particles is more accurate than gravimetric mass weighing**

CARB Evaluation of the European PMP Protocol on a Trap-Equipped Diesel Vehicle



Significant number of sub-30* nm particles



** 30nm and smaller = nucleation mode particles*

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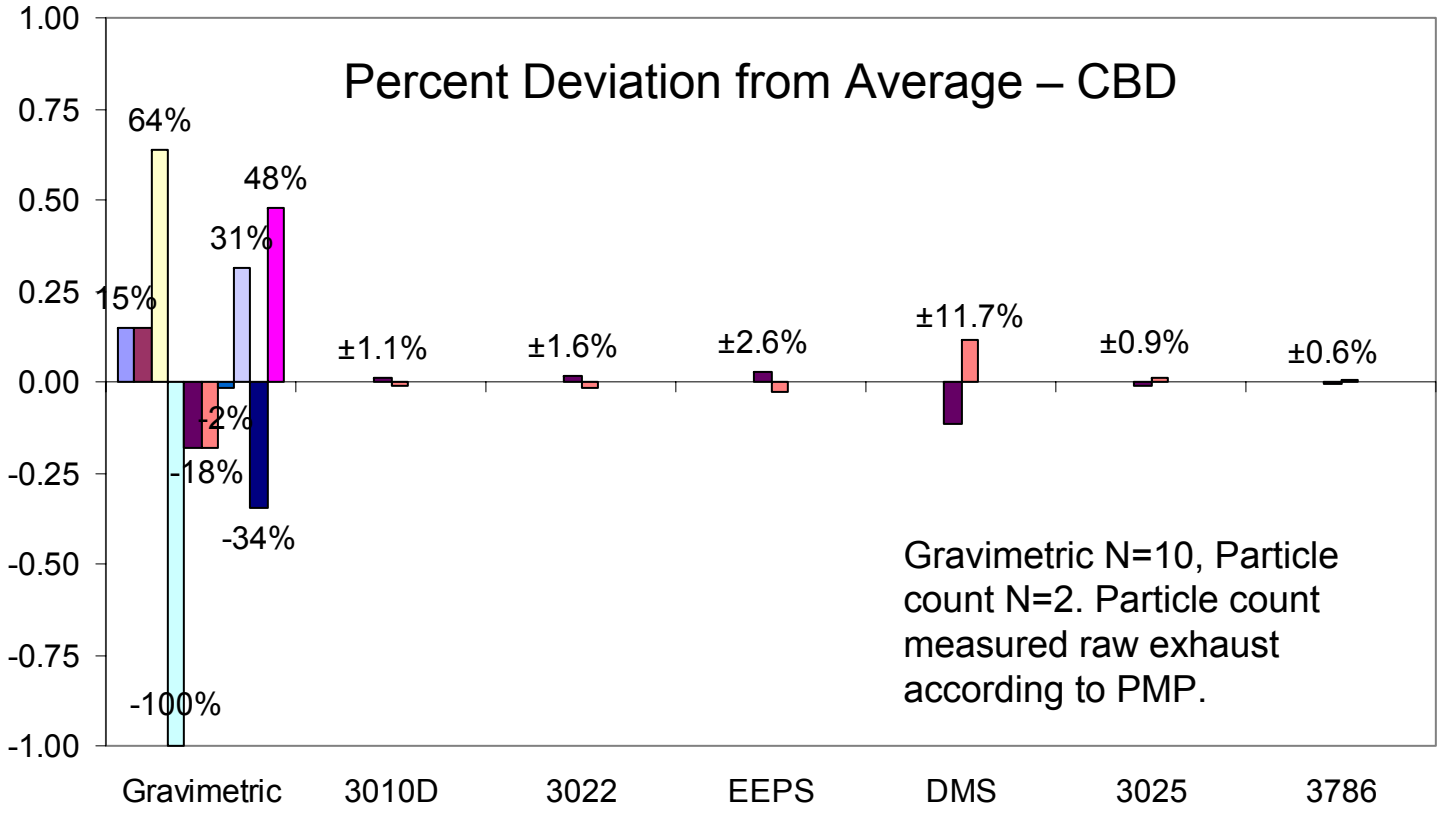
Herner and Ayala, CRC On-Road Emissions Workshop, San Diego, **2006**

Post trap particle counting statistics appear superior to gravimetric measurement



Size cut [nm]: →	23	7	5.6	5.6	3	2.5

Herner and Ayala, CRC On-Road Emissions Workshop, San Diego, **2006**

Summary

- The sources of ultrafine particles are numerous. Mobile sources is one area of keen interest.
- Ultrafine particles constitute a small fraction of PM mass, but dominate the fraction of particle number.
- Some credible research evidence suggests that PM mass emission control may not equal particle number emission control.
  - *Is the laboratory measurement of ultrafine particles capturing the ultrafine particles found on the road?*
  - *Agreed-upon methodologies for measurement of ultrafine particle emissions are needed*
- New instrumentation offers significant potential.
- European developments are an important advancement that foster debate and promote progress.